SAVONIA

OPINNÄYTETYÖ - **AMMATTIKORKEAKOULUTUTKINTO**
TEKNIIKAN JA LIIKENTEEN ALA

# PRODUCT DEVELOPMENT OF SPECIAL EQUIPMENT FOR UNDERGROUND CONSTRUCTION

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SAVONIA-AMMATTIKORKEAKOULU

OPINNÄYTETYÖ
Tiivistelmä

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|---|---|
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| Koulutusohjelma<br>Kone- ja tuotantotekniikan koulutusohjelma | |
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Tiivistelmä

Opinnäytetyö tehtiin Normet Scandinavia AB:lle Etteplan Design Center Oy:n alaisuudessa kevään 2015 aikana. Työ käsitteli maanalaiseen rakentamiseen tarkoitetun erikoislaitteen tuotekehitystä. Tarkoituksena oli tutkia vaihtoehtoisia ratkaisuja kustannussäästöjen aikaansaamiseksi. Tämän työn aikana saatujen tulosten avulla voidaan arvioida laitteelle tehtäviä jatkotoimenpiteitä.

Tässä työssä hyödynnettiin valmistusmyötäisen suunnittelun menetelmiä. Työssä tutkittuja menetelmiä olivat muun muassa levytyötekniikan ja ostokomponenttien hyödyntäminen sekä kustannussäästöjen aikaansaaminen standardoimalla. Työ tehtiin tutkimalla aiempia malleja ja analysoimalla mahdollisia kehityskohteita. Kaikki tutkimusvaiheen aikana kerätyt kehityskohteet kirjattiin myöhempää tarkastelua varten. Kohteiden keräyksen jälkeen potentiaalisimpia kehityskohteita tarkasteltiin tarkemmin. Tarkastelussa kiinnitettiin erityisesti huomiota paljon osia sisältäviin osakokonaisuuksiin sekä useita työvaiheita vaativiin osiin. Näihin kohtiin etsittiin yksinkertaisempia ratkaisuja etsimällä Internetistä vastaavia tuotteita. Tämän lisäksi tietokoneella mallintamalla haettiin vaihtoehtoisia rakenneratkaisuja. Ratkaisuissa pyrittiin minimoimaan muutosten vaikutus muuhun rakenteeseen.

Työmenetelminä olivat ostokomponenttien ja symmetrian hyödyntäminen, osien yhdistäminen yhdeksi levytyötekniikan avulla sekä rakenteiden yksinkertaistaminen. Työssä käytettiin apuna Autocad Mechanical -ohjelmaa aiempien CAD-piirustusten tutkimisessa. Tuotetiedonhallintajärjestelmän kautta tutustuttiin laitteen rakenteeseen. Solidworks ja Autodesk Inventor –ohjelmia hyödynnettiin 3D-mallien tutkimisessa sekä uusien ratkaisujen mallintamisessa. Lisäksi perinteistä kirjallisuutta hyödynnettiin kattavan pohjatiedon saamiseksi. Lopputuloksena saatiin esitutkimus laitteen kehityskohteista. Tämän tutkimuksen avulla voidaan tehdä kehitysehdotus jatkotoimenpiteitä varten.



Avainsanat
tuotekehitys, kustannusten alentaminen, DFM, DFMA, valmistusmyötäinen suunnittelu

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

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Abstract

This thesis was done while working at Etteplan Design Center Oy in spring 2015. The work was done for Normet Scandinavia AB. The subject was a product development project of special equipment for underground construction. The purpose of this project was to study alternative solutions for cost reduction. With this study, the development of this machine can be evaluated.

In this thesis, DFM, Design for Manufacturability methods was utilized for cost reduction. The used methods included for example redesigning sheet metal parts and utilization of both purchasable parts and standardization. The work was done by studying existing designs and analyzing possible development targets. While exploring existing models, potential targets were noted down for a follow-up. After collecting the targets, the most potential ones were chosen for a closer analysis. In this analysis, attention was especially paid to complicated structures.

The study was carried out by searching solutions from different suppliers and utilizing DFM methods. These methods included for example symmetric design, utilizing purchased components and merging parts together. The work was mainly done with Computer Assisted Design programs. Autodesk Mechanical was used for studying existing drawings. Solidworks and Autodesk Inventor were used for studying existing 3D models and modeling new parts. Also literature about DFM was studied and utilized. As a result, preliminary survey for creating development suggestion was accomplished.



Keywords
Product development, cost reduction, DFM, DFMA

FOREWORDS

The subject of this thesis evolved while working at Etteplan Design Center Oy during studies. The job description was product data management in a conversion project. The target of the conversion project was special equipment for underground construction and the project was ordered by Normet Scandinavia AB. The task in the project was mainly to feed product data information to a PDM system. The main idea of the thesis arose during this work.

For me, this thesis gave a good vision on product development and how things are done in practice.

I would like to thank my supervisors Jose Pietikäinen, Esa Hietikko and Timo Lipponen. Special thanks for Jarno Jukola from Etteplan Design Center Oy and Normet Scandinavia AB for giving me this opportunity to be a part of this project. I would also like to thank Marjo for helping and supporting me during the whole process.

This is a public version of the thesis.

Kuopio, May 7, 2015
Ville-Petteri Nousiainen

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TERMS AND ABBREVIATIONS

Etteplan DRAW = Service model which helps to convert customers' product models to a new format, for example from 3D models to drawings

Etteplan ITEM = Service model which can cover the whole PDM depending on the customers' needs

Etteplan CSC = Service model which assists when outsourcing abroad

Etteplan CORE = Service model for reducing costs by reducing parts, material costs and enhancing manufacturability

2D = 2-dimensional

3D = 3-dimensional

PDM = Product Data Management, which can include all information during the lifetime of a product

DFM = Design for Manufacturability

DFMA = Design for Manufacturing and Assembly

Brainstorming = Imaginative method for collecting ideas in a team

FEM analysis = Finite Element Method; for analyzing complicated structures by dividing the structure to smaller elements, usually done by a computer

CAD = Computer Assisted Design

Benchmarking = Analysis for competive products

Fillet = Rounded corner

Off-the-shelf part = Purchased part, usually standardized

# 1 INTRODUCTION

Design for manufacturability, DFM, has been an important part of industrial engineering for decades. By designing products in terms of machines and methods, manufacturing will become more cost efficient. DFM was originally intended for easing automatized manufacturing. Although utilizing these methods eases manual manufacturing and assembly as well. (Anderson 2015-04-25; Huhtala, Pulkkinen 2009; Lempiäinen, Savolainen 2003)

Both mass producing and Build-to-Order companies can take advantage of DFM. Competing against mass produced and inexpensive products may be difficult especially in countries that have a high standard of living. In this case, DFM is the most reasonable solution for reducing excessive costs from the manufacturing process. Therefore, the cost of an end product will be reduced. With DFM methods, high quality, enhanced manufacturing and low manufacturing costs can be achieved. (Anderson 2015-04-25; Huhtala, Pulkkinen 2009; Lempiäinen, Savolainen 2003)

The methods used in this thesis will be based on DFM methods used at both Normet and Etteplan. During this project, structures from a machine will be explored and the found development targets will be collected. These targets will be analyzed by their value for creating cost reduction. For this evaluation, a few examples will be taken into closer examination. As a result, a preliminary survey for creating development suggestion will be done.

# 2 COMPANY DETAILS

The thesis was carried out at Etteplan Design Center and the customer corporation was Normet Scandinavia Ab. Co-operation between these companies is based on Etteplan's service models as ordered by Normet Scandinavia Ab. In this case, the service included converting the earlier 2D CAD models of the machine to new 3D-models and drawings. The service also included product data management of this conversion project.

## 2.1 Etteplan Design Center Oy

Etteplan Design Center Oy is a company that is specialized in engineering and techical documention services. Etteplan Design Center is a subsidiary of Etteplan Group. Etteplan's business in Finland is centered to Etteplan Design Center Oy. (Etteplan Oyj 2015-04-20)

Etteplan was founded in 1983 and it is the leader on its own market area in Finland. In Europe, Etteplan is one of the largest companies that provide technical documentation solutions. Customers are usually international and significant producers of industrial machines and devices. Etteplan has offices in Finland, Sweden, Netherlands, China and USA. (EtteplanOyj 2015)

For its customers, Etteplan offers multiple service models. These service models make it easy to define the needs of its customers and to meet these needs in an adequate way. The service models that lay the base for this thesis are CSC, DRAW and ITEM. The work done in this thesis is similar to Etteplan's CORE -service model. (Etteplan Oyj 2015-04-18a, Etteplan Oyj 2015-04-18b, Etteplan Oyj 2015-04-18c and Etteplan Oyj 2015-04-18d)

## 2.2 Normet Scandinavia AB

Normet Scandinavia AB is specialized in developing and manufacturing of special equipment for underground construction. Normet Scandinavia, earlier Essverk Berg AB, is now a part of the Normet Group after an acquisition in 2011. It is located in Ludvika, Sweden and it offers solutions for underground construction in the whole Scandinavian area.

The equipment developed and manufactured at Normet Scandinavia belong to the Essverk product line. Sales, service and maintenance for other Normet products in Norway and Sweden are also handled via Normet Scandinavia AB. (Normet Scandinavia AB, 2015-04-20)

## 2.3 Normet

With a half century of experience in developing, manufacturing and selling equipment for underground mining and tunnel construction, Normet has become one of the market leaders with over 9,000 delivered machines. Normet also provides construction chemicals for mining and tunnel industries and takes care of maintaining these products and operating processes around them. Normet Group's head office is located in Iisalmi, Finland. Also the main research and development is done there. Normet has offices for example in Australia, Chile and Sweden. (Normet Oy, 2015-04-22)

# 3 DEVELOPMENT METHODS USED IN THIS THESIS

Product development is a process where an idea can eventually transform into an innovation. The development process can be divided into a few main phases by the lifecycle of the product. The process starts with setting tasks and planning the product development process. Development starts with designing the product. After this testing and prototyping has been done, the product can enter production. After production, the product must be sold to customers. The last phase is using the product. During this phase, the product might need some maintenance and other additional customer services, like spare parts. (Pahl, Beitz, Feldhusen, Grote 2007, 3) All these steps should be taken into account when developing new products. Understanding the lifecycle of the product in overall, helps to manage overall costs of a product.

Most of the product costs are determined at an early stage of the design. Even 80 % of the manufacturing costs can be influenced by the designer (Hietikko 2013, 18). For making business profitable and to keep ahead of rivals, it is important for companies to evaluate their products. This thesis is concentrating on the preliminary product development phase. In this phase, the whole structure is surveyed and arosen development ideas are collected. These ideas are analyzed with DFMA methods and at the end of the thesis, development proposals will be presented.

## 3.1 Cost reduction

*"The key to profitable growth is to focus on the products with the most potential, not to dilute resources on the most products"* (Anderson 2010, 386). When developing existing products this means that it is necessary to concentrate on changes that create a value increase for the whole product.

Etteplan CORE is a service that utilizes DFMA tools for creating cost reductions. In addition to traditional DFMA methods, Etteplan CORE also provides a service for concrete cost reducing solutions. For example, these can be material and component sourcing for example in China. (Etteplan Oyj 2015-04-18a) A similar approach for reducing product costs will be used in this thesis.

In order to reduce overall costs of a product, it must be understood what overall costs includes. Overall costs can be divided into two types:

1. Direct costs, which includes e.g. costs of manufacturing the product, labour and materials.
2. Indirect costs include e.g. costs of maintaining the factories and stores.

Some of the costs can be variable. These costs can depend on batch sizes, materials and assembly methods. Fixed costs remain the same for a period of time. The costs of a product usually include both fixed and variable costs. However, in a design process only variable costs are usually taken into account. (Pahl et al. 2007, 535)

## 3.2 Design For Manufacturability

*"DFM is the process of proactively designing products to (1) optimize all the manufacturing functions: fabrication, assembly, test, procurement, shipping, delivery, service and repair, and (2) assure the best cost, quality, reliabilty, regulatory compliance, safety, time-to-market, and customer satisfaction."* (Anderson 2015-04-25)

DFM can be used as a cost reducting tool in a product design projects. It is important to understand earlier designs' pros and cons. Using DFM will be easier if the past of the product is known and weaknesses are identified. (Lempiäinen and Savolainen 2003, 31)

Although product assembly is going to be done by a manual assembly, it is good to use same design principles as in an automatic assembly. This eases the manual assembly and makes it easier when upgrading from a manual assembly to an automatic assembly. (Lempiäinen and Savolainen 2003, 81) This also makes it easier to manufacture parts with different subcontractors and it will help to get the best bids for manufacturing these components.

Key guidelines for DFM can be summarized in the following way:

1) Learn from earlier designs, which have gone through all production phases.
2) Take into account ease of fabrication, processing and assembling the product during design process.
3) Follow specific design guidelines for manufacturing processes like welding, bending and milling.
4) Use paired parts when possible. This means no left or right handed parts.
5) Use symmetry when possible. If it is not possible, make parts as asymmetrical as possible.
6) Design high quality. Total costs will increase if faulty parts have to be replaced.
7) Minimize used manufacturing machines and develop products concurrently with manufacturing processes.
8) Design parts which can be manufactured as few phases as possible.
9) Specify and optimize used tolerances for easy manufacturing.
   (Anderson 2015-04-25)

All these guidelines can be summarized in one phrase: Keep It Simple. When product structure is simplified, required steps from design to final product are decreased. During early stage of design, every assembly should be revised for excessive parts. Utilizing DFM methods, parts could be combined or even eliminated. (Bramble 2015-04-27)

## 3.3 Computer Assisted Design

Several computer programs were used during this project. 3D design programs like Autodesk Inventor and Solidworks eases the work of designer and engineer. These programs are very versatile for different types of engineering work. It makes it easier to optimize parts for assemblies and to understand the whole structure. Making drawings are quite simple, compared to work engineers had to do a few decades ago.

In large companies, there is compulsive need for managing all the information that is associated with product during its lifetime. For this need Product Data Management systems and programs were created. These systems can

help to manage every single bit of information. PDM also means a systematic method to control and develop products. (Sääksvuori and Immonen 2002, 13) The PDM system is a basic tool for teamworking engineers; it eases handling large amounts of product information.

The FEM analysis has become an important tool for engineers during past decades. It enables testing different types of materials, structures and configurations. It can decrease the need for prototyping and helps analyzing product functionality in high stress situations. Solidworks Simulation is a FEM analysis add-in for Solidworks. It can be used for optimizing even more complicated structures.

# 4 PRODUCT DEVELOPMENT IN THIS PROJECT

The project was started by studying the machine's 3D-models. The PDM system was used to get familiar with the architecture. During this process, potential development targets were collected and noted down. At first, the idea was just to collect potential development targets without getting too specific.

There are many ways to design a product that does the same thing. The difference is how to approach the problem being solved. In product development, important factors in design are cost, manufacturability and how the designed product solves the problem. In this thesis, DFM methods are utilized for investigating possible cost effective designs.

## 4.1 Categorizing targets

After the introductory research phase, a brainstorming session was held. During this brainstorming, ideas for making the product more cost efficient were listed:

- Reducing the number of items
- Unifying materials
- Enhancing manufacturability
- Standardizing parts and sub-assemblies
- Using purchasable components

This list was used when investigating earlier collected development targets. The list helped analyzing the needs of the targets. After going through the collected material about potential targets, the main development targets started to become clear.

## 4.2 Chosen targets

The main objects chosen for the thesis are item reduction via sheet metal solutions and by replacing existing designs with off-the-shelf parts. Also standardizing parts and materials were taken into account. Selected targets were evaluated with DFM guidelines. Using these guidelines reduces the need for evaluating every possible target with complicated cost calculations. These methods lead to a faster and easier manufacturing, reduced material costs and ease of assembly. These factors are a few of the many key components in the cost structure of a product. It is estimated that 60 % of the lifetime cost of a product can be influenced during the early design phase when deciding the product architecture. The manufacturing phase affects only 5 % of the total cost. (Anderson 2010, 5 and 90) This is the reason why every design should be revised carefully before it reaches the production phase.

## 4.3 Benchmarking

After the development targets had been chosen and the means for creating cost reduction had been analyzed, the next phase of the project, small-scale benchmarking, was initiated. Benchmarking is a way to analyze the product by comparing it to other similar products. This information can be used directly by utilizing purchasable compo-

nents or indirect by merging features to a new design. (Jack 2013, 44) It is possible that the competitor can make similar products better and with less expense. In this situation the manufacturability of the product should be evaluated for cost efficiency.

Information collected via benchmarking was used for deciding the best way to proceed with the chosen targets. During benchmarking, several supplier websites for each item were explored for better understanding of available solutions. In this project, there were no straight away solutions for the examined components. Nevertheless, it gave ideas for designing structures and a lot of new information about available components and different solutions.

### 4.4 Exploring PDM system for existing solutions

Due to the wide variety of developed machines, there are several existing designs for different kinds of mechanical structures in Normet's PDM system. When developing new components, it is important to check earlier designs for similarities. It can be time saving for a designer to use earlier designs. It creates reliability for a machine using parts that have already been in production. This will also reduce items added to the PDM system, which will lower the total cost for managing the parts. (Anderson 2004, 341 and 375)

Reusing existing components can ease engineers' work due to the already proven concept. Even if the found component is not exactly as wanted, it could be used as a template. This can help when the intended part is complicated and there are similar ones already in production. It is important to check if the used design has some flaws, or if there are manufacturing problems. It should be also checked if the component is still in use or in production. (Anderson 2010, 184) If it has been removed from the production it could have some basic flaws that abstain from using it.

### 4.5 Standardization

Standardizing materials, parts and manufacturing methods can be a real game changer for companies that are moving towards more flexible manufacturing. Because standardization affects mainly on new products, it should be implemented as soon as possible.

Standardization can have an affect on a product in the following ways:

- Cost – by reducing the need for storage, inventory and fixed costs
- Quality – by reducing number of suppliers and decreasing risk of using wrong parts.
- Flexibility – by making the whole manufacturing process more fluent and easing logistics and setups.
- Responsiveness – by increasing co-operation between fewer suppliers, better partnerships are bonded, which can lead to more fluent collaboration. When using fewer parts, availability improves and suppliers can improve their product lines for better service. (Anderson 2010, 180–184)

Standardization is commonly used in mechanical industry. It eases the design process of a large scale production.

# 5 PURCHASABLE PARTS

Anderson's law:"*Never design a part you can buy out of a catalog*" (Anderson 2010, 186).

When using purchasable parts, there is no need for designing or manufacturing it. This means major time and cost savings. In most cases, purchasable parts are a lot cheaper than in-house produced parts due to the larger production amounts and specialization for manufacturing it. Off-the-shelf parts are usually quite standardized and all the testing, prototyping and fine tuning have already been done. (Anderson 2010, 186-187)

Using off-the-shelf parts may reduce costs when utilization is done in an early stage of design. If the structure is designed beforehand, it may be difficult to embed purchased part to the design. (Anderson 2010, 186–187) In this case, the structure had been designed earlier. This makes it more difficult to find the suitable parts and if one is found, there may be need for some changes for the structure around it. This could easily consume the achieved cost savings due to the changes needed for the whole structure. This is why utilizing off-the-shelf parts should be done either at the beginning of the design process or when upgrading larger structure of an earlier design. In this thesis, use of purchasable parts will be evaluated.

Off-the-shelf parts should be used when using standardized or mass produced parts. Also if parts need special equipment for manufacturing or a lot of storage room, purchased parts should be utilized. However, part should not be bought off-the-shelf if it differs too much from its original use or if it could be done better and with lower cost by in-house manufacturing. (Anderson 2004, 344–346)

# 6 SHEET METAL DESIGN

There are a lot of different guides for designing good sheet metal products. After all, they all have similar principles and working methods. In this project, several sources for designing cost efficient sheet metal products are used.

Utilizing design for manufacturing and assembly, DFMA, methods for a sheet metal design can reduce the number of components in an assembly. In this project, the existing component assembly will be redesigned using sheet metal methods. This can affect on the appearance of the product. The idea of this redesign is to give a new point of view for the earlier solution and to prove that parts can be reduced.

The design process of the sheet metal component followed these steps during the project:

1. Analyzing the earlier structure and sketching designs for a new architecture.
2. Choosing the sheet metal material for the product. The main criteria were:
    a. Sufficiency for the intended use
    b. It should already exist in the PDM system
    c. It should have a wide variety of thicknessess
3. After the material was chosen, possible manufacturing methods like laser cutting and bending were checked. The thickness and strength of the chosen material will affect on manufacturing methods.
4. Designing 3D parts and finetuning the assembly to work as wanted. Also a few instructions for a sheet metal design were implemented:
    a. The distance between the edge of the hole and the bent plate should be at least 1.5 x the thickness + the bend radius (Lempiäinen and Savolainen 2003, 54).
    b. The distance between the center of the slotted holes and the edge of the plate should be at least 1.5 x the diameter of the hole (Teräsrakenteiden suunnittelu ja mitoitus 2010, 90–91).
    c. The flange that comes after the bend should be at least twice as much as the plate thickness (Lempiäinen and Savolainen 2003, page 56).
    d. The minimum bending radius for the material was taken from the material datasheet.
5. Solidworks Simulation was used for a basic material analysis and optimizing the material thickness.
6. Analyzing the designed structure.

DFM methods like symmetry, simplification and merging several parts to one will be utilized when designing the sheet metal components. All of these methods helps to reduce components, enhance manufacturability and eventually lead to cost reduction. Symmetric parts can be used on both sides. Therefore, there is no need for left and right handed parts. Simplifying the product and merging parts reduces needed manufacturing procedures. (Anderson 2010; Lempiäinen and Savolainen 2003)

# 7 CONCLUSIONS AND DISCUSSION

The objective of this thesis was to collect possible development targets. The main idea of these targets was cost reduction with DFM methods. Information collected can be used when evaluating the need for further product development.

During this thesis process, the whole structure of this machine was explored and at the same time possible development targets were noted down. For this thesis, most potential targets were chosen for closer evaluation. By utilizing DFM methods, these targets could create significant cost reduction. The study included examples from different categories. These categories were standardization, utilization of purchased parts and sheet metal development. General development ideas for these categories were presented.

As a result, a collection of potential development targets was identified. This thesis serves as a preliminary study. The complete development suggestion report could be done with a help of this thesis.

In this thesis, a few development targets were identified. For this machine, the best development methods were enhancing manufacturability of sheet metal parts, standardization and utilization of purchased parts.

DFM methods can reduce manufacturing costs and ease the whole process for both automatized and manual manufacturing. It reduces time needed for the whole process, including for example part manufacturing and assembly. For the best benefit, DFM should be utilized as early as possible in the design process.

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